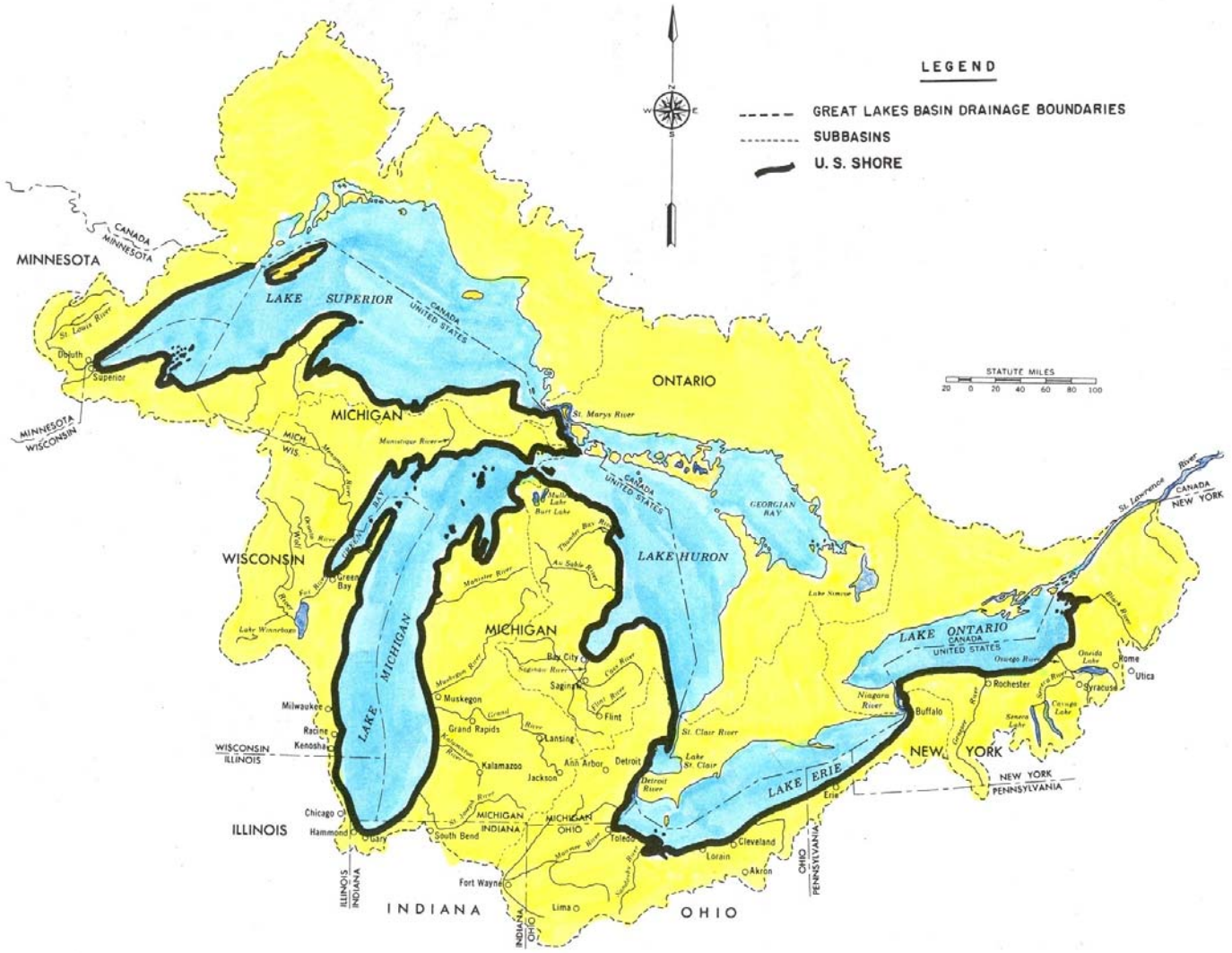
Great Lakes Navigation

Great Lakes Navigation Structures

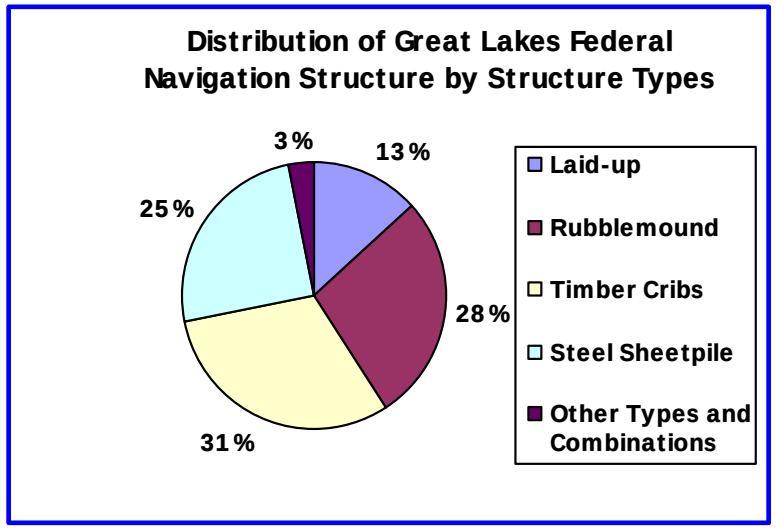
Condition Assessment

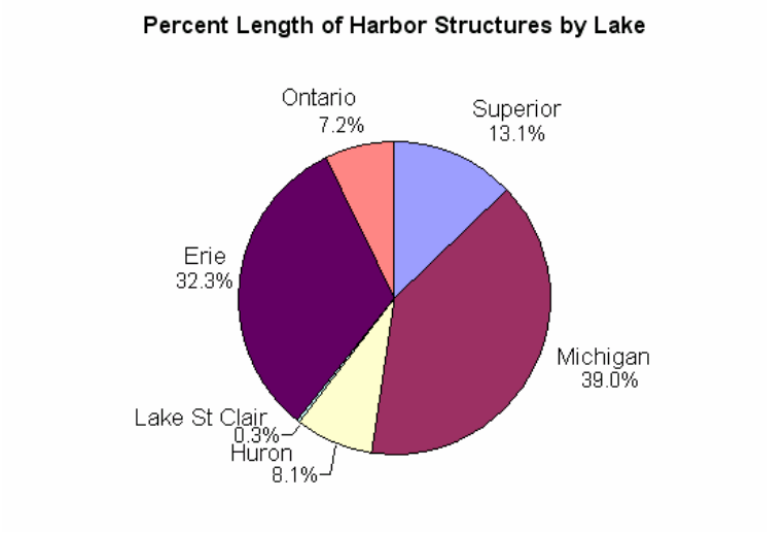


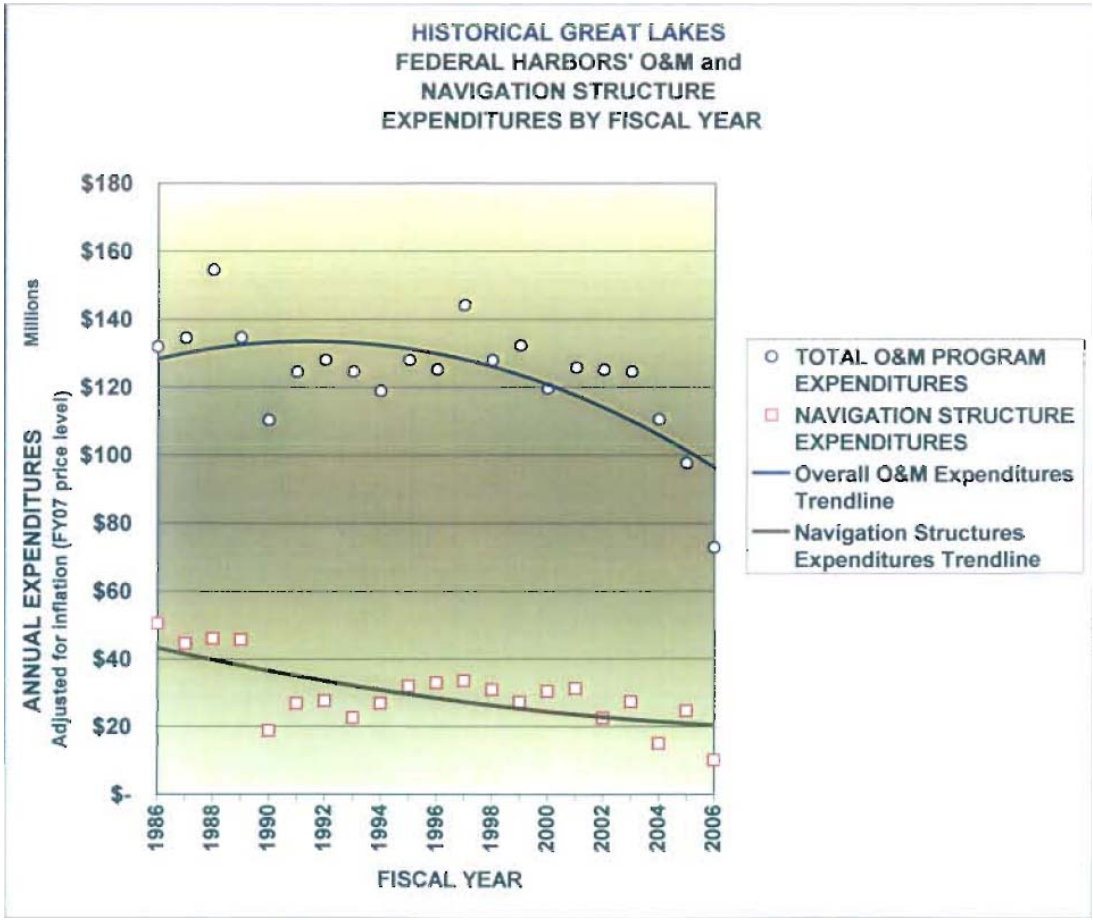
Great Lakes Navigation

Great Lakes Navigation Structures

Condition Assessment







- Approximately 104 miles of navigation structures form the 117 Federal Harbors on the Great Lakes.
- Most structures were built between 1860 and 1940.

Great Lakes Navigation Structures

Condition Assessment

Presentation Overview

- Great Lakes Regional Breakwater Assessment Team
- Completed and ongoing activities
- Future directions / needs

Great Lakes Navigation Structures

Condition Assessment

Great Lakes Breakwater Assessment Team (BAT) Established in FY2007

We are a regional team composed of members from LRB, LRE, and LRC, and the GL Coastal RTS, and reporting to Linda Sorn, Chief of TSD, LRC

LRB – **Paul Bijhouwer, Civil Engineer, CELRB-TD-OT**
Shanon Chader, Chief, Coastal and Geotechnical Section

LRC – **Tim Kroll – Civil Engineer, CELRC-TS-C-T**

LRE – **Tom O'Bryan – Acting Chief, Lake Michigan Area Office**
Chris Lindeman – Civil Engineer, LRE-ET
Tom Johnson – Civil Engineer, LRE-LK-K-C

Michael Mohr, GL Regional Technical Specialist for Coastal Engineering

The team's primary mandate is to establish a consistent and technically sound assessment process for the GL Region, to enable budgetary decisions to be made in a manner that minimizes risk.

Great Lakes Navigation Structures

Condition Assessment

BAT Partnerships:

The team leverages the knowledge of engineering specialists and researchers within the Coastal Community of Practice.

Provide detailed expertise regarding navigation structure design, performance, inspection, and condition rating.

Develop relationship between navigation structure condition and function.

Develop impacts to shipping industry due to changes in harbor wave climate.

Develop impacts to coastal communities due to storm damage and flooding resulting from navigation structure failures.

Great Lakes Navigation Structures

Condition Assessment

BAT Functions

Oversight of annual condition assessment inspections to ensure adequacy and consistency.

Periodic performance of collective inspections.

Completion of Structure Index ratings in accordance with ERDC procedures (REMR Guides).

Annual reevaluations of structural condition with respect to impact on harbor operations.

Great Lakes Navigation

Great Lakes Navigation Structures

Condition Assessment

The Great Lakes BAT has completed the assessment and ranking of an initial group of structures.

FY07/08 mandate was to collectively inspect the worst structures on the GL, as preliminarily identified by the home Districts.

This effort focused on eight harbors which the team visited, and two additional harbors for which continuous still photography and video were made available.

Inspections employed ERDC REMR condition assessment methodologies.

Team used a multi-factor ranking system (akin to an algorithm) to develop consequences for use in setting repair work priorities.

Contract (major repair / rehab) work packages for inspected structures were rated for the initial FY10 Great Lakes navigation budget submission.

In FY08/09, work packages executed by government fleet (routine maintenance and repair) will be included.

Great Lakes Navigation Structures

Condition Assessment

Condition assessment inspections examined all navigation structure components.

Steel Sheet Pile Structures –
SSP walls, anchorages, cap, scour protection

Rubble Mound/Laid-Up Stone Structures –
cross section, core stone, armor stone

Wood Crib/Concrete Cap Structures –
Crib material, concrete cap, scour protection

Other Elements –
Safety (railings, walking surfaces, etc.)

Great Lakes Navigation

Great Lakes Navigation Structures

Condition Assessment

Challenges with use of REMR Guides

Suitability to structure types

CI = FI, which cannot be definitively determined within the time and funding scope of an annual budgetary asset management process

SI = Thrown away?

Draft revised REMR rating scale uses 1 – 6 vs. 0 – 100. Averaging formulas need to be modified to account for scale reversal.

Great Lakes Navigation Structures

Condition Assessment

Table 6. Rating guidance for loss of armor interlock.

Structural Rating	Description NOTE: Interlock ratings based on Hudson Coefficient of at least 3.5.
	No or Minor Damage
85 to 100	Loss of interlock is minimal.
70 to 84	A few armor units may have lost contact with adjacent units by up to 1/4 of the unit diameter.
	Moderate Damage
55 to 69	Loss of contact or interlock with adjacent units in some places, however separation rarely exceeds ½ of the unit diameter. Bridging of units may occur in isolated locations.
40 to 54	Many adjacent armor units are separated by up to ½ of the unit diameter. Some armor units are completely separated from adjacent units and are acting independently. Many of the loose units show signs of being easily rocked or shifted by normal or light storm waves.
	Major Damage
25 to 39	Many armor units are loosely nested and act alone. Separation between adjacent units commonly exceeds one unit diameter.
10 to 24	Most armor units are loosely nested and are acting alone.
0 to 9	Nearly all visible armor units are loosely nested and are acting alone. At this stage, many of the armor units have also been lost.

Challenges with use of REMR Guides

REMR-OM-24 presents rating guidance based only on written description. A visual reference standard for inspections would help remove some of the subjectivity of the ratings, making them more precise.

Standards are needed for rating laid-up stone structures.

Major Damage:

Structural Rating	Description	Photo Example
25 to 39	Many armor stones have either shifted or been displaced by greater than a foot. There may be significant bridging between armor layers along with the loss of individual armor stones within the reach.	

Great Lakes Navigation

Great Lakes Navigation Structures

Condition Assessment

Challenges with use of REMR Guides

Compatibility with Budget EC Risk Matrix

SI Mappable to Probability / Condition?

How do we get at Consequences?

EC 11-2-193
12 May 08

TABLE V-3 NAVIGATION RELATIVE RISK RANKING MATRIX

Consequence / Condition		Probability/Condition Classification				
		F Failed	D Inadequate	C Probably Inadequate	B Probably Adequate	A Adequate
Consequence/Economic Impact	I	25	24	22	19	15
	II	23	21	18	14	10
	III	20	17	13	9	6
	IV	16	12	8	5	3
	V	11	7	4	2	1

High Relative Risk
Med-High Relative Risk
Medium Relative Risk
Low Relative Risk
Minimal Relative Risk

Great Lakes Navigation

Great Lakes Navigation Structures

Condition Assessment

Table V-9 Navigation Structures Probability/Condition		
Condition Level		**Probability / Condition**
GOOD	A	Failure to the point navigation will be measurably impacted is unlikely within budget cycle Project fully accomplishing its intended purpose
MODERATE	B	Low risk of failure to the point navigation will be measurably impacted within budget cycle
POOR	C	Medium risk of failure to the point navigation will be measurably impacted within budget cycle
FAILING	D	High risk of failure to the point navigation will be measurably impacted within budget cycle
FAILED	F	Condition severely restricts or halts navigation within budget cycle

Great Lakes Navigation

Great Lakes Navigation Structures

Condition Assessment

Table V-10 Navigation Structures Consequence/Economic Impact	
Consequence Level	**Consequence Description**
1	Demonstrated highest economic impact[1] **Imminent** life safety impact Critical to safe navigation by commercial vessels at High Use Navigation Project (>10M tons) Critical to safe navigation at DoD Strategic Ports
2	Demonstrated High economic impact[1] **Probable life safety impact.** **Probable impacts to subsistence harbors/harbors of refuge.** High economic loss (5 - 10 M Tons) Probable life safety impact Alternate modes of transportation exist for Energy Distribution Facilities, but at a higher cost than water borne transportation
3	Demonstrated Moderate economic impact[1] **Possible life safety impact.** **Possible impacts to subsistence harbors/harbors of refuge.** Moderate economic loss (1 - 5 M Tons) Possible life safety impact
4	**Low economic impact[1] and no life safety impact. Little impacts to subsistence harbors/harbors of refuge.** Low economic impact (<1M Tons) No life safety impact
5	**Negligible economic and no life safety impact. No impacts to subsistence harbors/harbors of refuge.** Negligible economics (Recreation Harbors, No commercial Activity) No life safety impact.

[1] Thresholds and basis for economic impact are under development. One measure of economic impact can be demonstrated using rate savings benefit, transportation cost savings, or damages avoided.

Great Lakes Navigation Structures

Condition Assessment

Given the inability to perform detailed analysis required to rigorously determine consequences, an assessment was made using a weighted ranking algorithm. Scores were then mapped to Budget EC Consequence Levels

Ranking algorithm elements used four categories. Each category had multiple valuation concepts and risk factors. The four categories and examples of each are as follows:

Category 1 – Value of Harbor Node to Overall GLNS
3-year Average Annual Tonnage

Category 2 – Value of Harbor Node to Local Community
Value of Infrastructure Protected by Harbor, “Additional Harbor Missions" Rating

Category 3 – Significance of work package/harbor element to overall Harbor
Ranking of component to Harbor function, Additional Component Missions Rating

Category 4 – Project work package/harbor element performance measures
Condition Index, Comparative Rate of Degradation, Comparative Cost of Repair, Harbor Lake Level, COE Hired Labor Forces Utilization

Great Lakes Navigation Structures

Condition Assessment

Inspection and Rating Procedure

Field inspection consisted of complete viewing of all structures in a harbor by boat, with collection of continuous still photography and video. Walkover inspection of some structures was also done.

REMR forms were then completed by the BAT in the office, with reference to field notes and the photographic and video record.

A work package justification package was then prepared for each project, documenting the need for the work.

An example follows:

Great Lakes Navigation

Great Lakes Navigation Structures

Condition Assessment

Lorain Harbor, Ohio – Continuous Still Photography (stitched)

Great Lakes Navigation

Great Lakes Navigation Structures

Condition Assessment

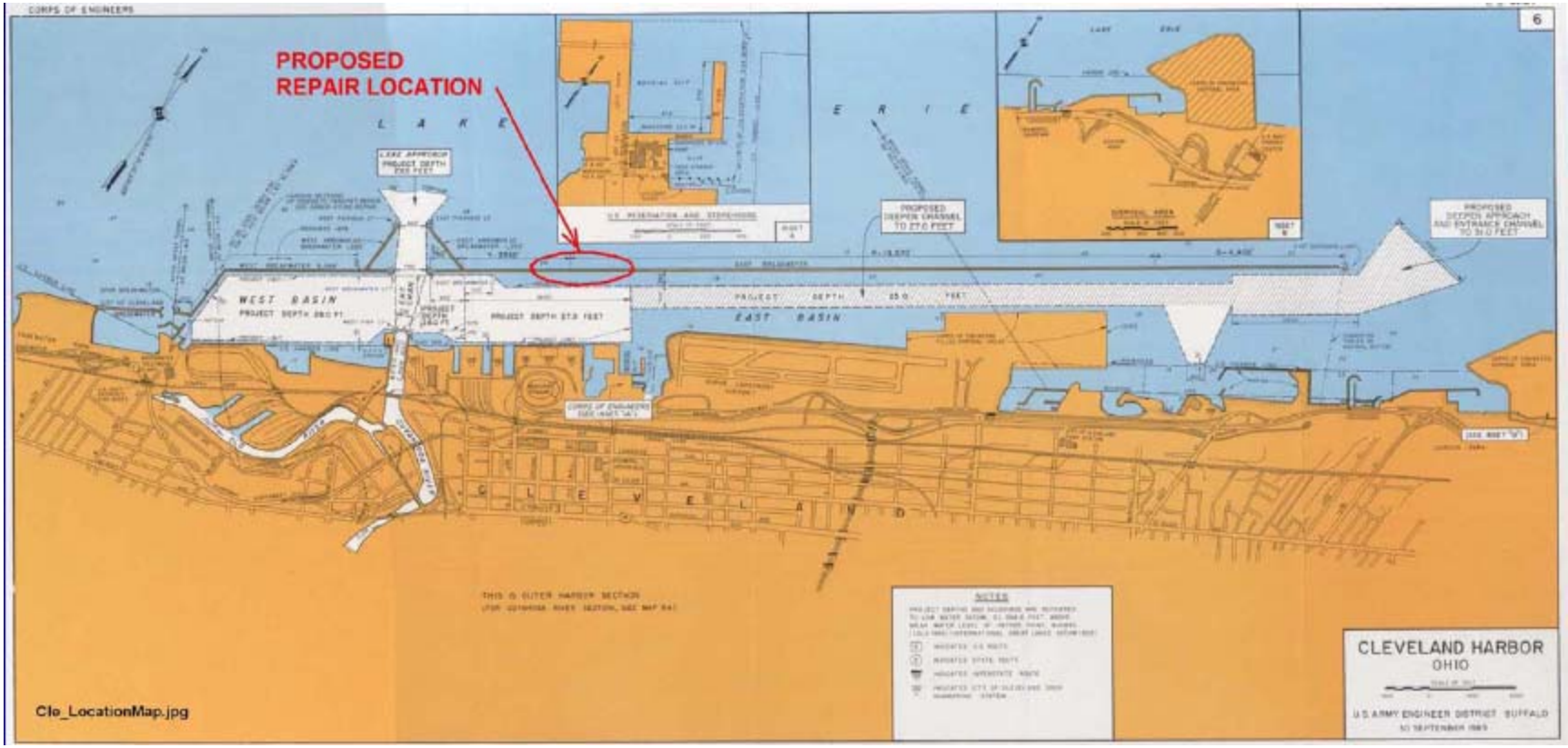
Cleveland Harbor, Ohio – Oblique Aerial Photo

Great Lakes Navigation

Great Lakes Navigation Structures

Condition Assessment

Cleveland Harbor, Ohio – Project Map

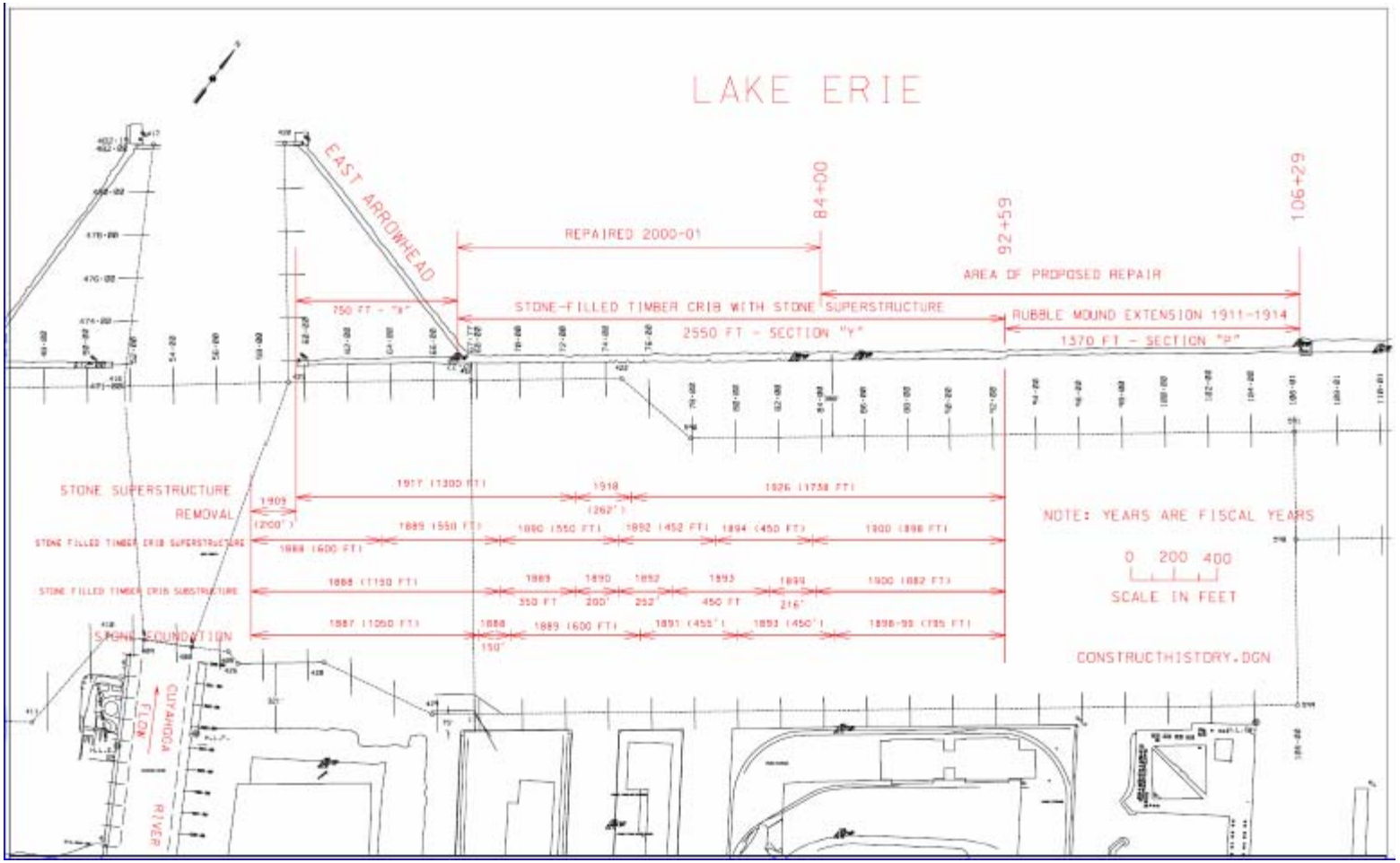


Great Lakes Navigation

Great Lakes Navigation Structures

Condition Assessment

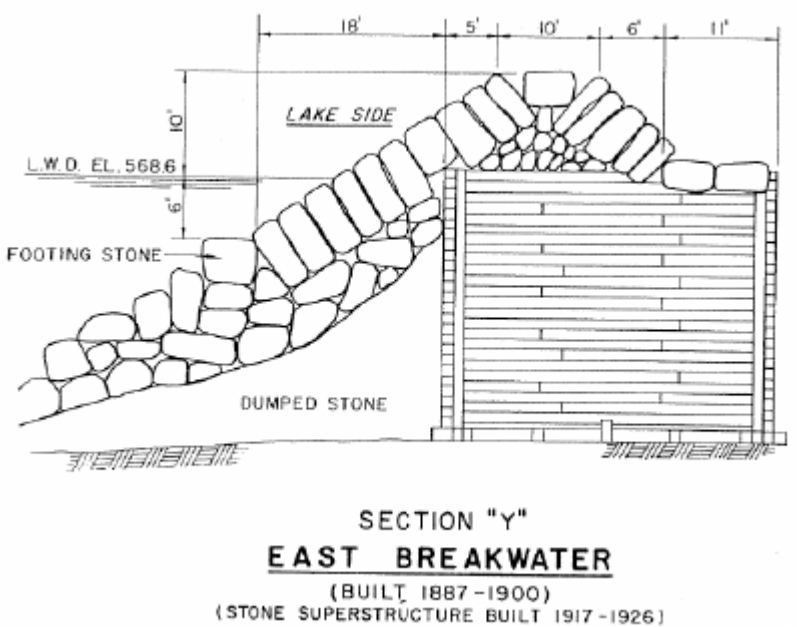
Cleveland Harbor, Ohio – Repair History



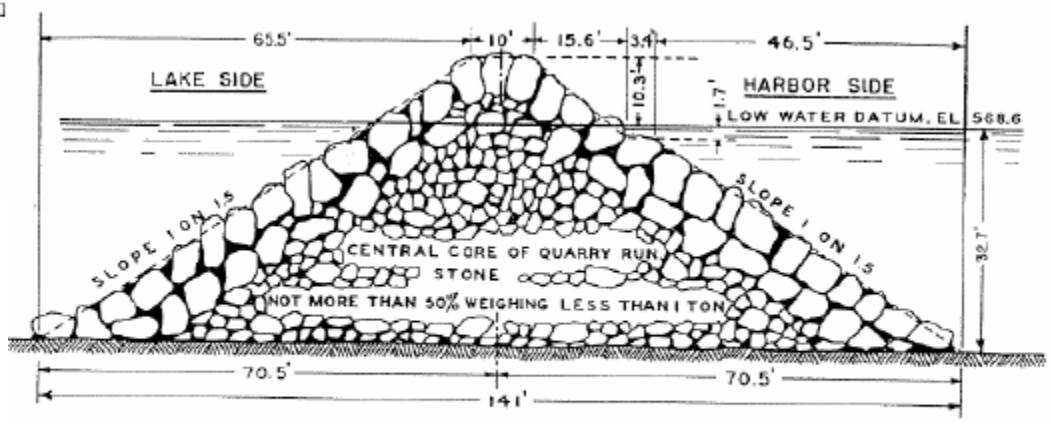
Great Lakes Navigation Structures

Condition Assessment

Cleveland Harbor, Ohio – Structure Cross Sections



SECTION "Y"
EAST BREAKWATER
(BUILT 1887-1900)
(STONE SUPERSTRUCTURE BUILT 1917-1926)



SECTION OF EAST BREAKWATER -P-
(BUILT 1903-1915)

Great Lakes Navigation

Great Lakes Navigation Structures

Condition Assessment

Cleveland Harbor, Ohio – Damage Photos

STATION 84+00 – PREVIOUS REPAIR AT RIGHT SIDE OF PHOTO

Photo dated 27 Aug 2007

Great Lakes Navigation

Great Lakes Navigation Structures

Condition Assessment

Cleveland Harbor, Ohio – Damage Photos

Great Lakes Navigation

Great Lakes Navigation Structures

Condition Assessment

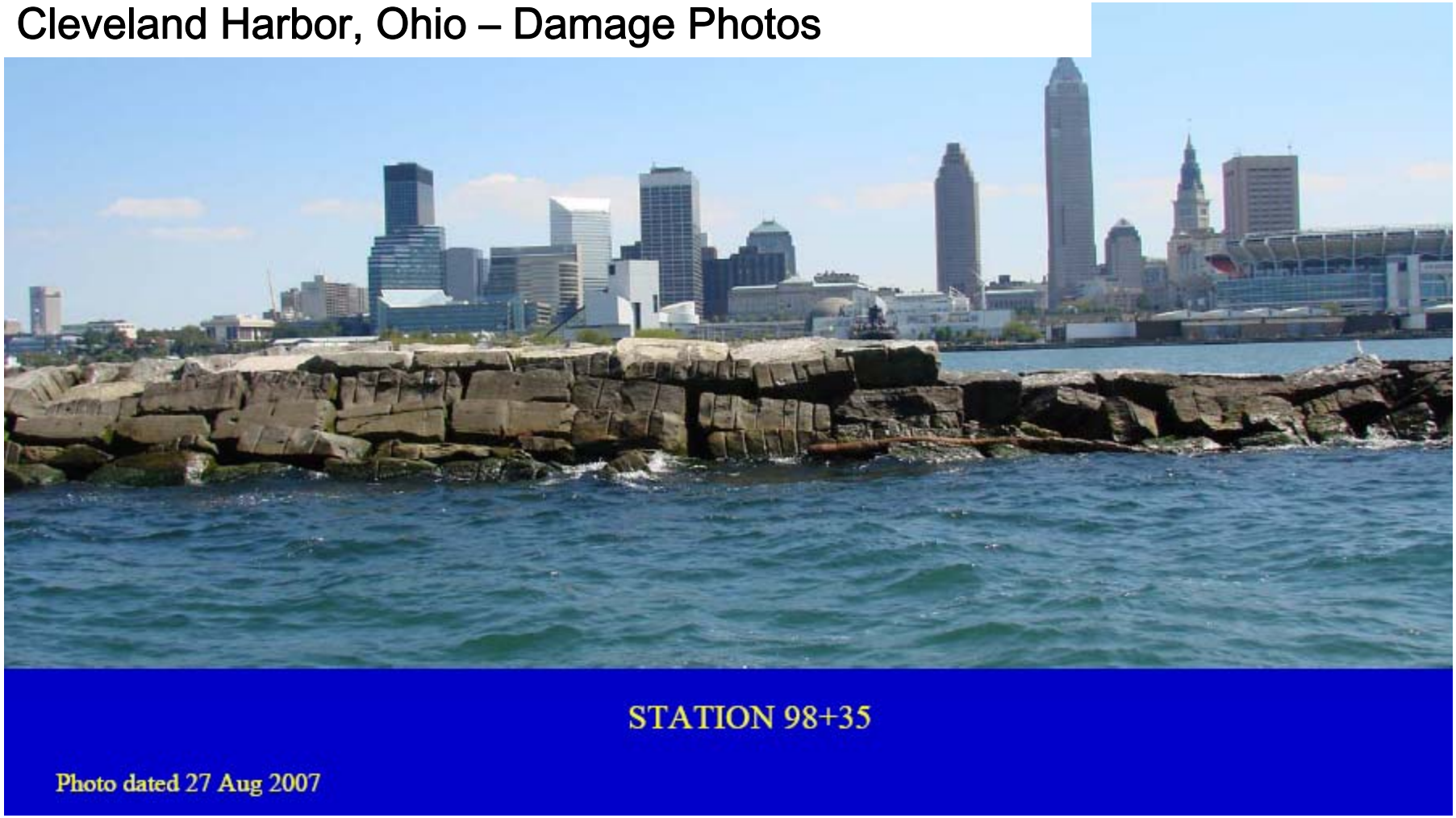
Cleveland Harbor, Ohio – Damage Photos

Great Lakes Navigation

Great Lakes Navigation Structures

Condition Assessment

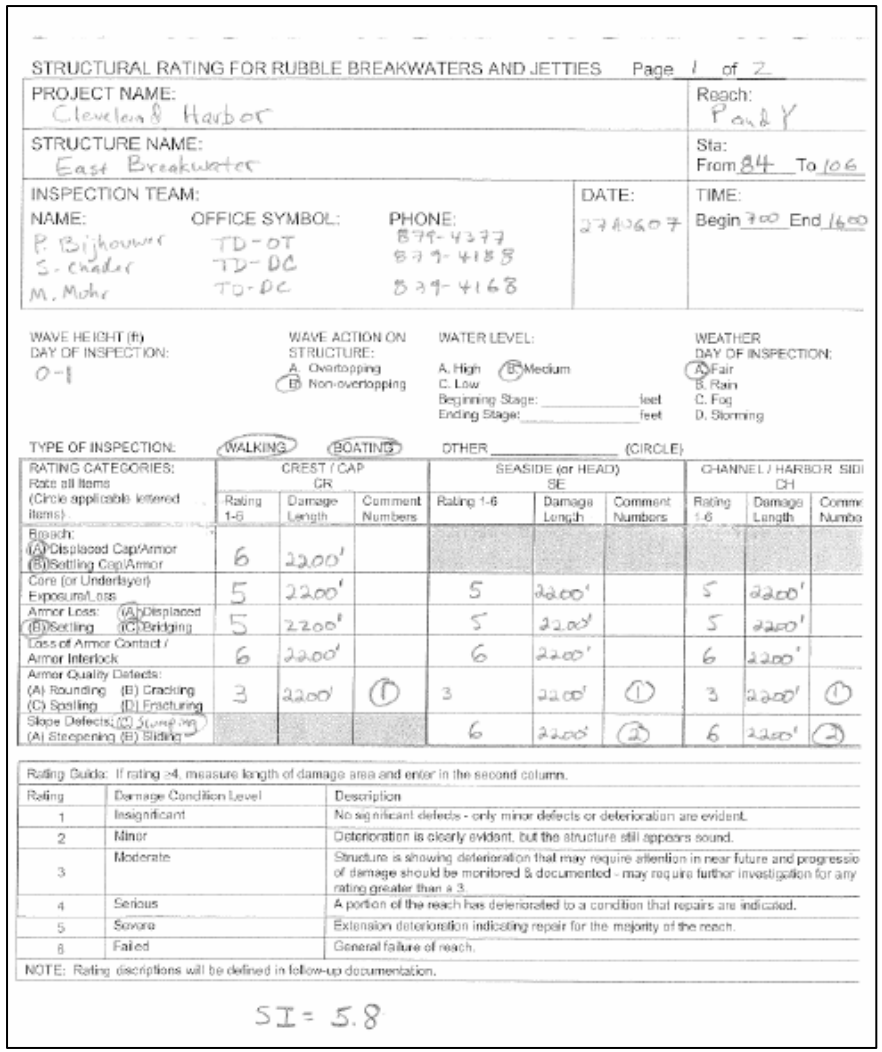
Cleveland Harbor, Ohio – Damage Photos



Great Lakes Navigation Structures

Condition Assessment

Cleveland Harbor, Ohio – SI Rating Form



STRUCTURAL RATING FOR RUBBLE BREAKWATERS AND JETTIES Page 1 of 2

PROJECT NAME: Cleveland Harbor — Reach: Pool Y

STRUCTURE NAME: East Breakwater — Sta: From 84 To 106

INSPECTION TEAM:

NAME:	OFFICE SYMBOL:	PHONE:
P. Bijhouwer	TD-OT	879-4377
S. Chader	TD-DC	879-4185
M. Mohr	TD-DC	879-4168

DATE: 27 AUG 07 — TIME: Begin 700 End 1600

WAVE HEIGHT (ft) DAY OF INSPECTION: 0-1

WAVE ACTION ON STRUCTURE: A. Overtopping (B) Non-overtopping

WATER LEVEL: A. High (B) Medium C. Low — Beginning Stage: _____ feet — Ending Stage: _____ feet

WEATHER DAY OF INSPECTION: (A) Fair B. Rain C. Fog D. Storming

TYPE OF INSPECTION: (WALKING) (BOATING) OTHER _____ (CIRCLE)

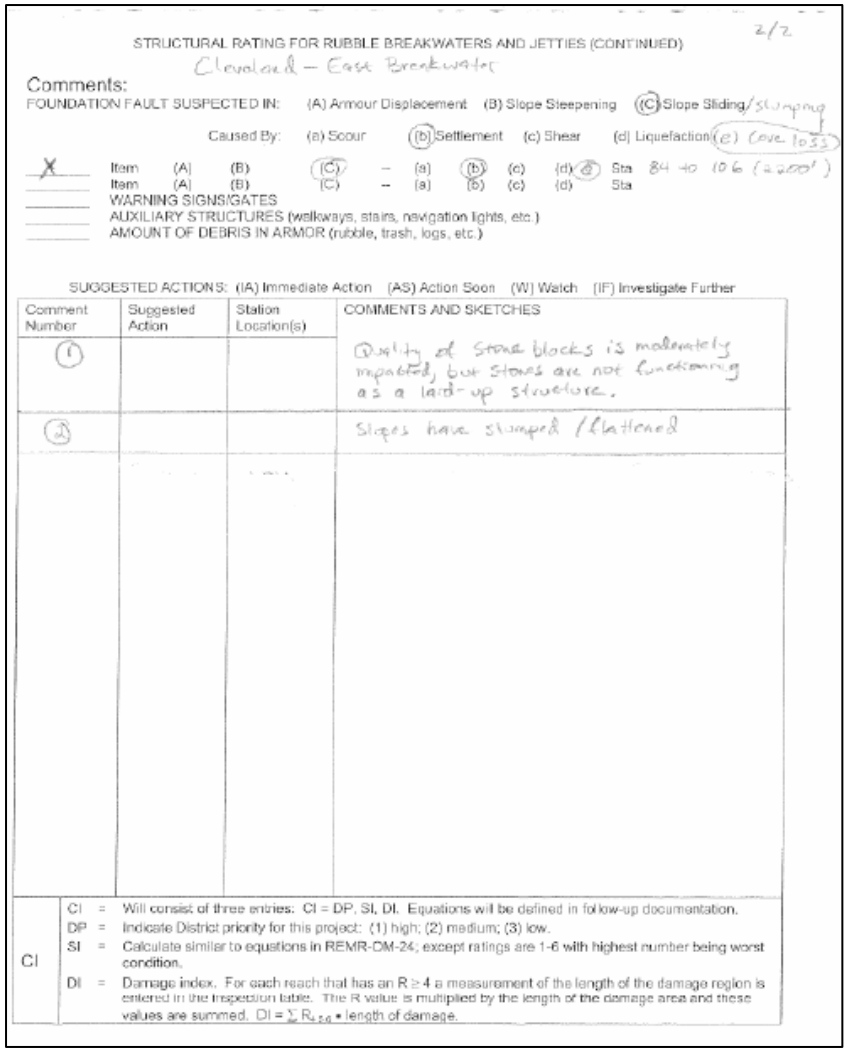
RATING CATEGORIES: Rate all items (Circle applicable lettered items)	CREST / CAP CR			SEASIDE (or HEAD) SE			CHANNEL / HARBOR SIDE CH		
	Rating 1-6	Damage Length	Comment Numbers	Rating 1-6	Damage Length	Comment Numbers	Rating 1-6	Damage Length	Comment Numbers
Breach: (A) Displaced Cap/Armor (B) Settling Cap/Armor	6	2200'							
Core (or Underlayer) Exposure/Loss	5	2200'		5	2200'		5	2200'	
Armor Loss: (A) Displaced (B) Settling (C) Bridging	5	2200'		5	2200'		5	2200'	
Loss of Armor Contact / Armor Interlock	6	2200'		6	2200'		6	2200'	
Armor Quality Defects: (A) Rounding (B) Cracking (C) Spalling (D) Fracturing	3	2200'	(1)	3	2200'	(1)	3	2200'	(1)
Slope Defects: (C) Slumping (A) Steepening (B) Sliding				6	2200'	(2)	6	2200'	(2)

Rating Guide: If rating >4, measure length of damage area and enter in the second column.

Rating	Damage Condition Level	Description
1	Insignificant	No significant defects - only minor defects or deterioration are evident.
2	Minor	Deterioration is clearly evident, but the structure still appears sound.
3	Moderate	Structure is showing deterioration that may require attention in near future and progressio of damage should be monitored & documented - may require further investigation for any rating greater than a 3.
4	Serious	A portion of the reach has deteriorated to a condition that repairs are indicated.
5	Severe	Extensive deterioration indicating repair for the majority of the reach.
6	Failed	General failure of reach.

NOTE: Rating descriptions will be defined in follow-up documentation.

SI = 5.8



STRUCTURAL RATING FOR RUBBLE BREAKWATERS AND JETTIES (CONTINUED) 2/2

Cleveland – East Breakwater

Comments:

FOUNDATION FAULT SUSPECTED IN: (A) Armour Displacement (B) Slope Steepening (C) Slope Sliding/Slumping

Caused By: (a) Scour (b) Settlement (c) Shear (d) Liquefaction (e) Core loss

X Item (A) (B) (C) – (a) (b) (c) (d) Sta 84 to 106 (2200')

Item (A) (B) (C) – (a) (b) (c) (d) Sta

WARNING SIGNS/GATES

AUXILIARY STRUCTURES (walkways, stairs, navigation lights, etc.)

AMOUNT OF DEBRIS IN ARMOR (rubble, trash, logs, etc.)

SUGGESTED ACTIONS: (IA) Immediate Action (AS) Action Soon (W) Watch (IF) Investigate Further

Comment Number	Suggested Action	Station Location(s)	COMMENTS AND SKETCHES
(1)			Quality of stone blocks is moderately impacted, but stones are not functioning as a latch-up structure.
(2)			Slopes have slumped / flattened

CI

CI = Will consist of three entries: CI = DP, SI, DI. Equations will be defined in follow-up documentation.

DP = Indicate District priority for this project: (1) high; (2) medium; (3) low.

SI = Calculate similar to equations in REMR-OM-24; except ratings are 1-6 with highest number being worst condition.

DI = Damage index. For each reach that has an R ≥ 4 a measurement of the length of the damage region is entered in the inspection table. The R value is multiplied by the length of the damage area and these values are summed. $DI = \sum R_{\geq 4} \cdot$ length of damage.

Great Lakes Navigation Structures

Condition Assessment

Cleveland Harbor, Ohio – Summary Statistics

- Recommended Repair Reach:
  - 84+00 – 94+00 (minimum) repair should extend to old light block at 106+29
- Total Length of Repairs = 1000 to 2229 feet
- Recommended Repair Method: Rubble mound stone overlay
- Estimated Cost of Repairs = $2.5 – 5.5 M
- Structural Index = 5.8

Great Lakes Navigation Structures

Condition Assessment

Future Directions and Needs

Supplemental Recon Study is incorporating a limited risk and economic analysis of the Cleveland East Breakwater FY10 Work Package. The time, scope and cost of this work exceeds what we can afford to do for every work package on an annual basis. Simplified analysis techniques are needed to allow assessment of structure function and linking to economic, life-safety, and environmental consequences.

A standard spatially referenced database of pertinent structure data (inspection records, photos, condition ratings, design and repair documentation, etc.) needs to be developed, populated, and maintained. Google Earth Coastal Infrastructure Database and National Levee Database can serve as useful models for this. By regulation, this data should be housed in the District eGIS (enterprise Geographic Information System).

Great Lakes Navigation Structures

Condition Assessment

Future Directions and Needs

Need to assess the benefit of preventative maintenance and repair work packages. This requires definition of time dependent structure degradation curves for “fix-as-fails” and “maintenance” scenarios. These will vary with structure type.